

# **Onset of Dormancy in the Copepod *Calanus pacificus californicus* Off Southern California**

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## **LONG-TERM GOALS**

Our long-range goals are to understand and, as feasible, predict the distribution and abundance of pelagic organisms, particularly in regard to their physical environment and its changes. The objective of the proposed research is to identify the mechanism that controls onset of dormancy in open-ocean copepods and thus explain spatial and temporal variation in dormancy response. Specifically we will examine whether the interaction between environmental conditions off southern California and variation in threshold stimuli for onset of dormancy within the *Calanus pacificus* population in this region can explain why part of the population becomes dormant during fall and winter while part of the population remains active and reproduces at the surface year-round. The proposed research will contribute to understanding of the following questions: (1) How does dormancy response affect population dynamics of open-ocean copepods? (2) What effect do short-term and long-term environmental changes have on dormancy response of open-ocean copepods? (3) Do latitudinal differences in dormancy response of populations with broad ranges result from latitudinal differences in environmental stimuli alone (i.e. is population response to stimuli the same throughout the range)? (4) What controls the buildup and dispersal of deep aggregations of dormant copepods?

## **OBJECTIVES**

- (1) To develop a new hormonal method for detecting preparation for dormancy in surface-dwelling, active *Calanus*.
- (2) To observe preparation for dormancy in surface copepods in the field using a hormonal method: to compare the timing of preparation for dormancy with other indicators of onset of dormancy including appearance and buildup of dormant *Calanus* at depth and increase of storage lipid in animals at the surface; and to compare timing of onset of dormancy with changes in environmental conditions that could trigger onset of dormancy.
- (3) To experimentally examine the effect of various stimuli, e.g. temperature, photoperiod, food concentration and quality, on preparation for dormancy.
- (4) To describe the vertical distribution of dormant *Calanus pacificus* at basin and non-basin stations off southern California. Specifically, to examine whether aggregations of dormant *Calanus* such as occur in Santa Barbara Basin (SBB) are found in other basins and whether basins are site of higher concentrations of dormant *Calanus* than non-basin locations.

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## APPROACH

To determine the mechanism that controls onset of dormancy, we are taking an integrated approach that includes development of a hormonal method to detect preparation for dormancy, field sampling of *Calanus* and environmental variables during the season when onset of dormancy occurs, and laboratory experiments designed to identify stimuli inducing dormancy. We wish to develop a method to detect preparation for dormancy for two reasons. First, detection of preparation for dormancy in *Calanus* in the field will make it possible to identify the environmental conditions that exist at the time of onset of dormancy. Second, detection of preparation for dormancy will aid in laboratory experiments, because it will allow dormancy to be detected without the necessity of identifying dormancy by lengthy suppression of development in *Calanus* fifth copepodites (CVs). The hormonal method takes advantage of changes in the molting hormone ecdysone during the molting cycle to identify preparation for dormancy. Since ecdysone is high just prior to molting, ecdysone levels in the “population” of *Calanus* at the surface should decrease when some or all CVs are preparing for dormancy compared to a “population” of CVs that are preparing to molt to adults. Because the relative duration of premolt, the molting stage in which ecdysone is high, can vary with temperature and food conditions, we will standardize CV ecdysone measurements by comparing them to ecdysone in CIVs, which should respond similarly to CVs to environmental conditions but which do not become dormant. Field sampling is being conducted at San Diego Trough (SDT), a 1200 m deep trough off San Diego, at two to four week intervals from April to November 2000. Each timepoint includes two pairs of MOCNESS (Multiple Opening and Closing Net and Environmental Sampling System) tows centered around noon and midnight and sampling to a maximum depth of 1100 m, profiles of T, S, O<sub>2</sub>, and Chlorophyll *a*, and water sampling for pigments and phytoplankton. Laboratory experiments will be conducted examining whether a range of environmental variables, including temperature, photoperiod, temperature period, and food concentration and quality, induce preparation for dormancy.

The vertical distribution of *Calanus pacificus* to a maximum depth of 2000 m is being examined at five basin and five non-basin locations off southern California in January, August, and October 1999 and October 2000 using a MOCNESS.

## WORK COMPLETED

Eight successful cruises to SDT have been completed in 2000. Enumeration of *Calanus pacificus* females, males, CVs, and CIVs has been completed for seven of the eight cruises.

Preliminary experiments examining whether photoperiod and temperature induce dormancy were conducted. Copepods, starting as third or fourth stage nauplii, were held in individual vials and exposed to the four possible combinations of high and low temperature (14° and 22° C) and long and short photoperiod (16L:8D and 8L:16D). They were fed a mixed phytoplankton diet every two days and examined microscopically every few days to determine their developmental stage.

Inclined plankton rollers for use in further dormancy induction experiments and hormone experiments were designed and built.

Enumeration of *Calanus pacificus* was completed for samples collected in October 1999 and for most stations in January 2000.

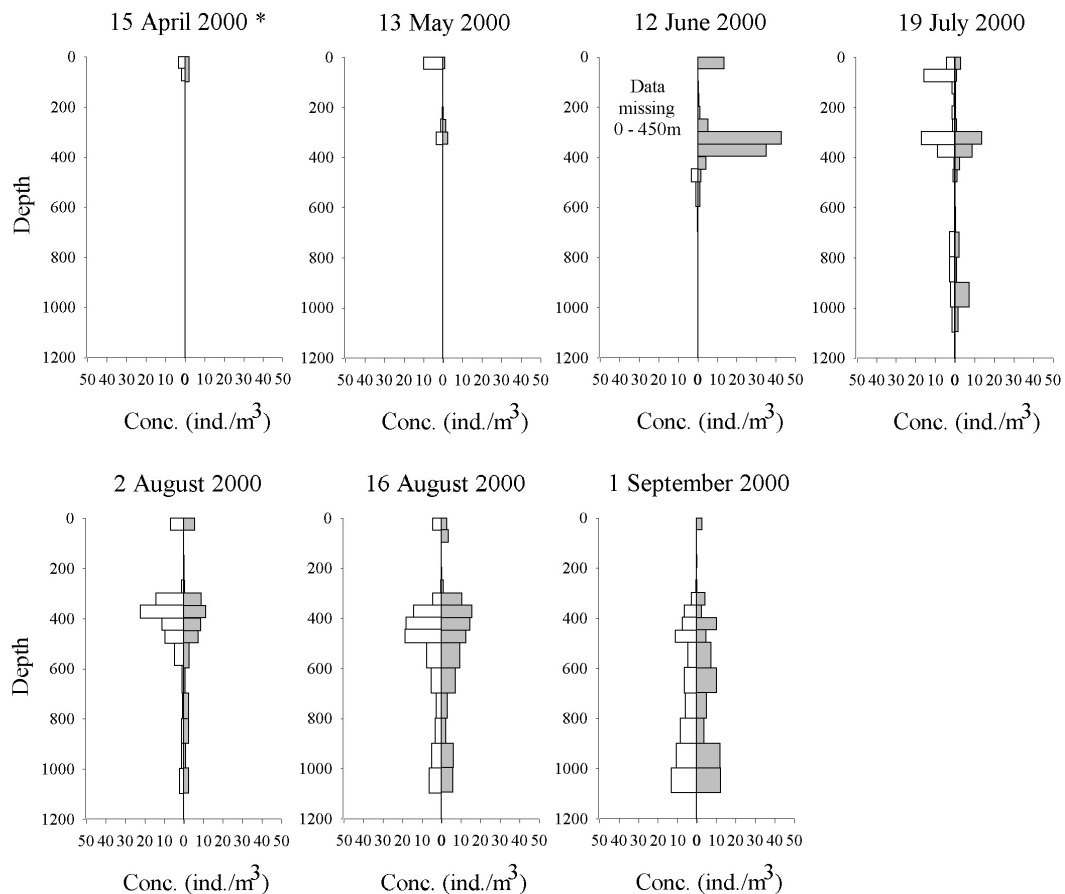
## RESULTS

Sampling of the vertical distribution of *Calanus pacificus* at the SDT from April through September 2000 revealed a buildup of CVs in deep water starting in mid-May (Fig. 1). In May and June, deep CVs were found mainly between 300 and 500m. In mid-July CVs also appeared between 700 and 1100m, and in August and September, the abundance of CVs below 500m increased while the abundance between 300 and 500m stayed approximately the same or decreased. It is currently uncertain whether the dormant status of CVs between 300 and 500m is different from CVs below 500m. A difference between these two groups is suggested by their bimodal distribution in mid-July, by the difference in the timing of appearance of CVs at the two depth ranges, and by the co-occurrence of a small layer of females and a few males with the shallower CV layer, between 300 and 350m. Alternatively, the bimodal distribution may result from the oxygen minimum zone located around 650 to 750m. Metabolic enzyme activity, wax ester content, and gut fluorescence of individuals in both layers will be measured to determine whether there are differences between these two layers.

The appearance of *Calanus* CVs at depth in SDT in June agrees with the seasonal pattern of deep CVs in the Santa Barbara Basin described by Osgood & Checkley (1997a). The temporal resolution of their study was, however, far coarser during the season of onset of dormancy, with sampling conducted only in February and June. Therefore it is not possible to resolve the timing of earliest descent of CVs, except that it is in June or earlier. In contrast to our study, Ohman *et al.* (1998) found only a very small layer of *Calanus* CVs between about 250 and 350m in SDT in June 1992. The concentrations of CVs in this layer were lower than the concentrations that we found in the deep layer in May 2000.

In preliminary experiments examining whether photoperiod and temperature induce dormancy, all surviving CVs molted to adult stages within ten days, even at cold temperatures. All but two surviving CVs molted to female adults. The two males were in the cold, short day treatment and the cold, long day treatment. The lack of onset of dormancy in this experiment could be attributed either to the treatments used not inducing dormancy or to inhibition of dormancy by physical disturbance associated with handling and small container size.

In October 2000, *Calanus* CV abundance, integrated over the depth range where they were dormant, was not significantly different at the basin stations and non-basin stations sampled. Dormant *Calanus* do not appear to be localized in Santa Barbara Basin but are widespread off southern California. In contrast with Santa Barbara Basin where a single depth stratum contained 75% of dormant CVs collected at all depths, dormant CVs at other stations had a fairly even distribution over a broad depth range. This suggests that the dense aggregation observed in Santa Barbara Basin is formed when descent of local CVs is arrested by the bottom or by the oxycline in the basin. Based on sampling during October 2000, formation of dense basin aggregations of dormant *Calanus* does not appear to be a widespread phenomenon in the Southern California Bight but is limited to Santa Barbara Basin, the shallowest basin in the region. The abundance of dormant *Calanus pacificus* in SBB in October 2000 was anomalously low compared to other autumns sampled (Alldredge *et al.*, 1984; Osgood & Checkley, 1997a,b). To determine whether the patterns identified in October 2000 persist in another, perhaps less anomalous, year, we will repeat our October 2000 sampling pattern in October 2001.



**Figure 1. Vertical distribution of *Calanus pacificus* CVs in the San Diego Trough. White bars represent daytime distribution, and gray bars represent nighttime distribution. \* Results for April 2000 are preliminary and may be in error by as much as 30%.**

## IMPACT/APPLICATIONS

Our San Diego Trough field study is the first time series to resolve the timing of descent of *Calanus* CVs off southern California. In the context of the proposed research, identification of the timing of appearance of CVs at depth is the first step toward identifying the environmental factors that are correlated with onset of dormancy. Characterization of the vertical distribution of CVs and enumeration of surface CVs is also a prerequisite for physiological measurements, including metabolic enzyme, lipid, and hormonal measurements. In addition, comparison of the timing of onset of dormancy off southern California with timing of onset of dormancy in Puget Sound (Osgood & Frost, 1994) may provide further insight into the environmental factor or factors that induce dormancy.

The distribution pattern of dormant *Calanus pacificus* CVs identified by this research suggests that all deep areas off southern California, not only basins, can act as sources for *Calanus pacificus* returning to the surface in spring. The temporal and spatial patterns of dormancy identified by this research will

be critical to modeling *Calanus* population dynamics in this region. In addition, identification of the factors that induce dormancy will provide a basis for prediction of short-term interannual variability in the timing of onset of dormancy. The ecdysone method will provide a means for identifying longer-term changes in the threshold stimuli that trigger dormancy, for example changes in response to global warming, in *Calanus* and other open-ocean copepod species.

## TRANSITIONS

The analysis of our first year of collections is still underway, as are our laboratory experiments. Thus, no transitions are reported at this time.

## RELATED PROJECTS

The work described here is largely independent of other projects. It comprises part of the Ph.D. dissertation research of Ms. Catherine Johnson at SIO. This work is related to the California Cooperative Fisheries Investigations (CalCOFI), in that collections are made on and data are used from the CalCOFI quarterly cruises. Drs. Carina Lange and Amy Weinheimer, of SIO, study particle deposition in the Santa Barbara Basin and are interested in our work in the overlying water column. In a larger context, there are numerous investigators worldwide interested in copepod diapause and its relation to plankton dynamics, fisheries, and ocean biogeochemistry.

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